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Influence on the Height of Stable Boundary Layers as seen in Large-Eddy Simulations

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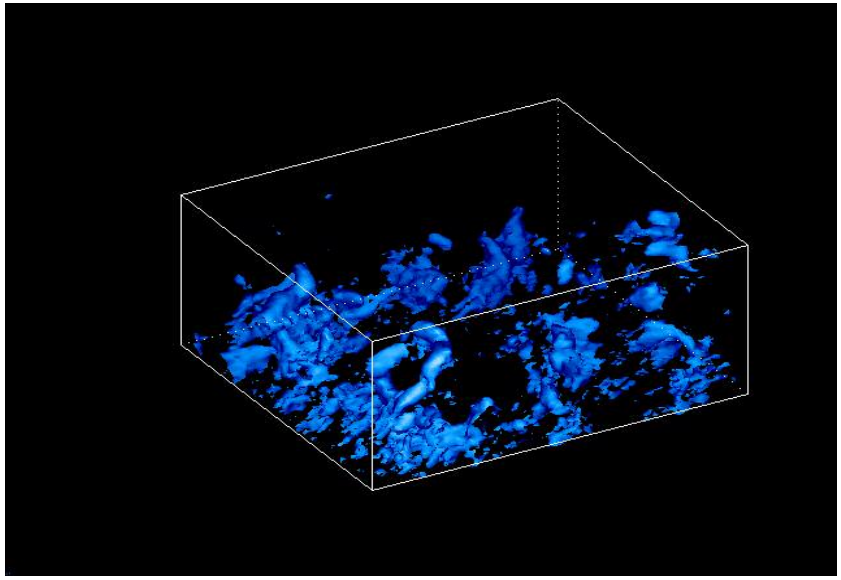

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Boundary Layer Height (h) is an Important Parameter in PBL models

- Boundary layer height is often used as a parameter in eddy-viscosity and eddy-diffusivity models for stable boundary layers
  - Brost and Wyngaard (1978)

$$K_m = k u_* h \frac{\left(\frac{z}{h}\right)\left(1-\frac{z}{h}\right)^{\frac{3}{2}}}{1+4.7\left(\frac{z}{h}\right)\left(\frac{h}{L}\right)}$$

  - Holtslag and Boville (1993)

$$K_h = k w_h z \left(1-\frac{z}{h}\right)^2$$

- Accurate parameterization of h is important for accurate estimate of PBL bulk Richardson number
- Accurate parameterization of h is essential for accurate prediction of dispersion under stable conditions

Stable Boundary Layer Height Parameterizations

- Zilitinkevich (1972)

$$h = C_z \left(\frac{u_* L}{f} \right)^{1/2}$$

- Zilitinkevich and Mironov (1996)

$$\left(\frac{fh}{C_n u_*} \right)^2 + \frac{h}{C_s L} + \frac{Nh}{C_i u_*} + \frac{h|f|^{1/2}}{C_{sr} (u_* L)^{1/2}} + \frac{h|Nf|^{1/2}}{C_{ir} u_*} = 1$$

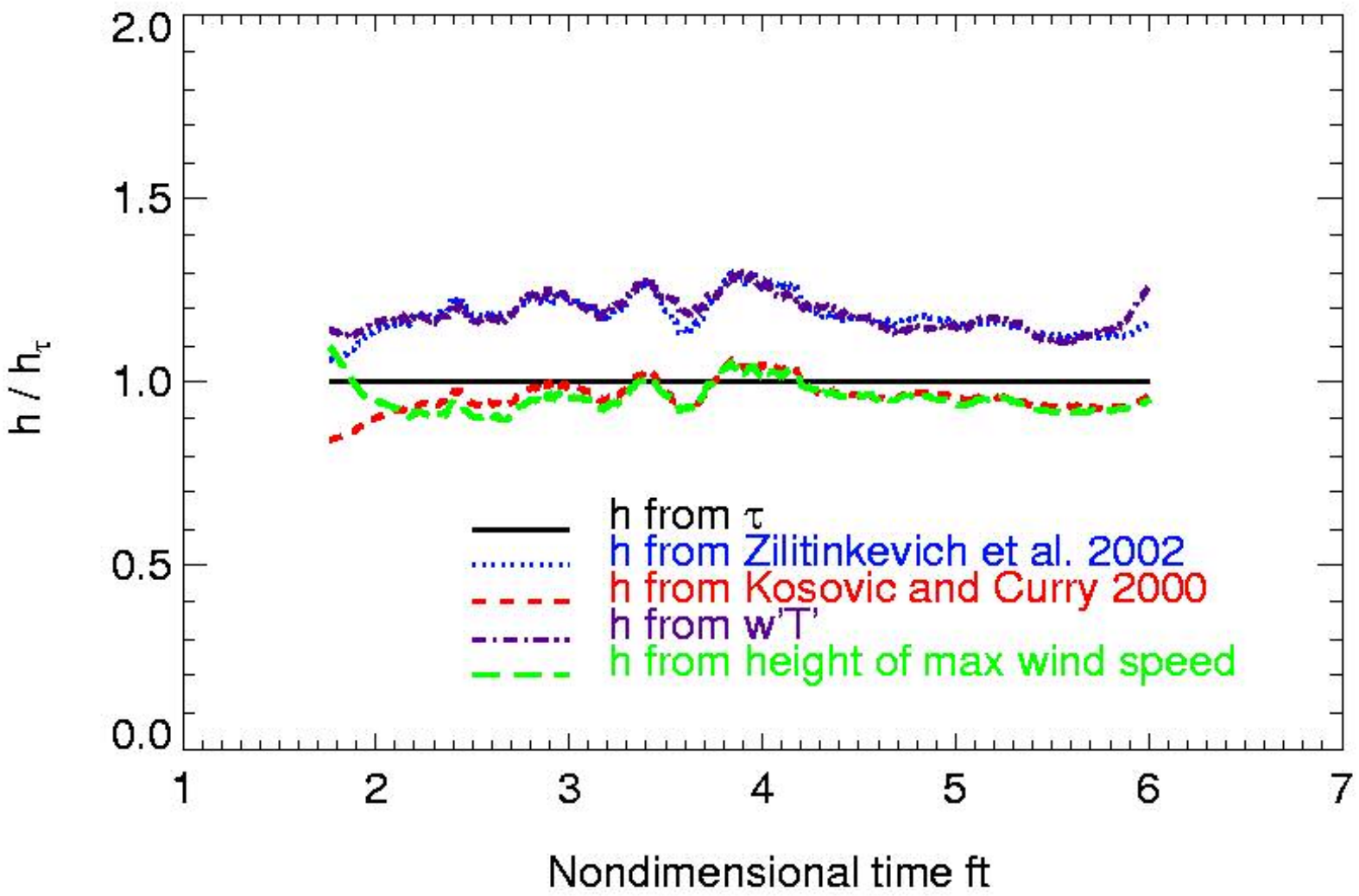
- Kosovic and Curry (2000)

$$\left(\frac{fh}{C_n u_*} \right)^2 + \frac{h}{C_s L} + \frac{h|f|^{1/2}}{C_s (u_* L)^{1/2}} = 1$$

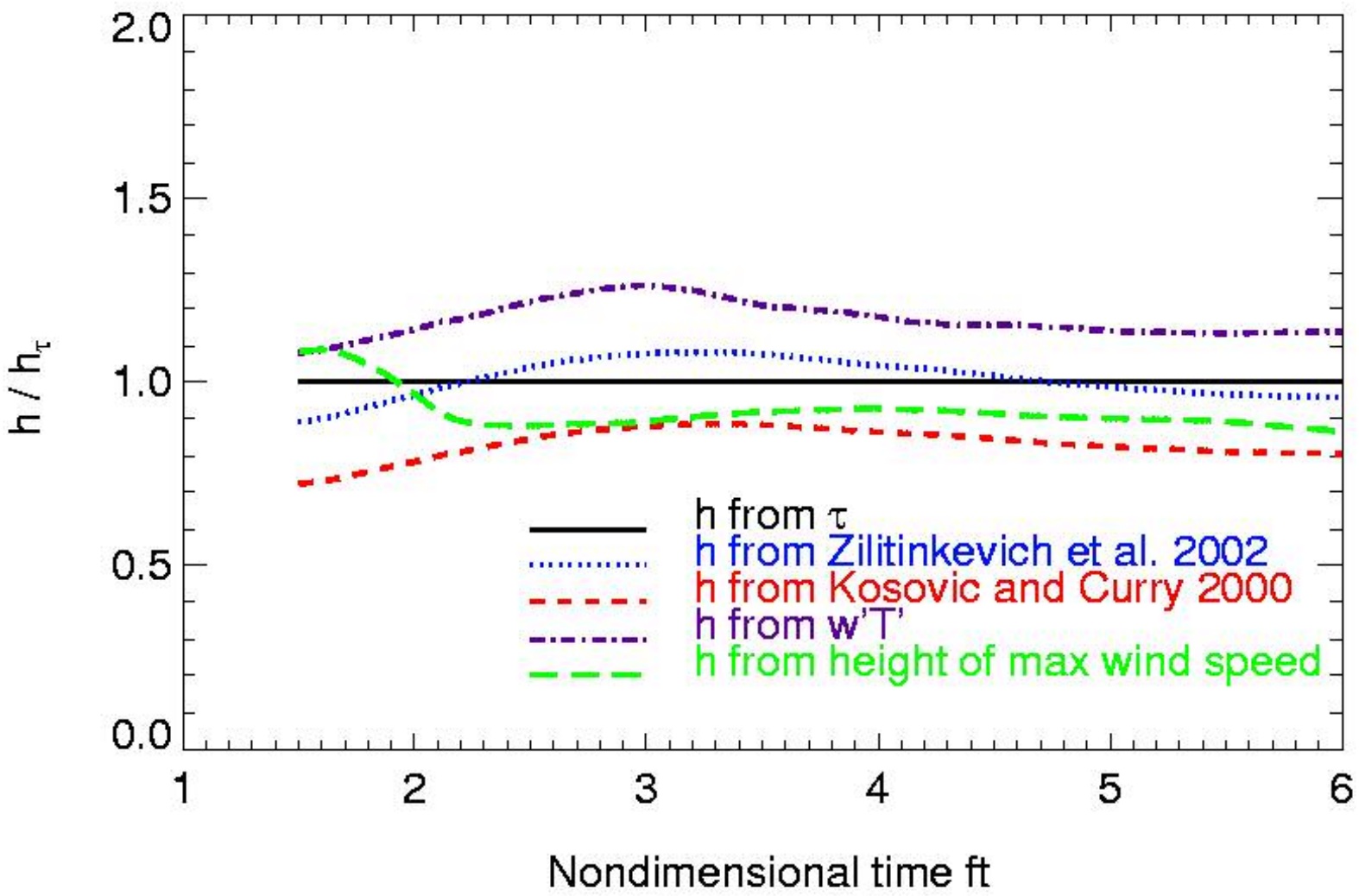
- Zilitinkevich et al. (2002)

$$h_e = C_R \frac{u_*}{f} \left[1 + \frac{C_R^2 u_* (1 + C_{UN} Fi)}{C_s^2 fL} \right]^{-1/2}$$

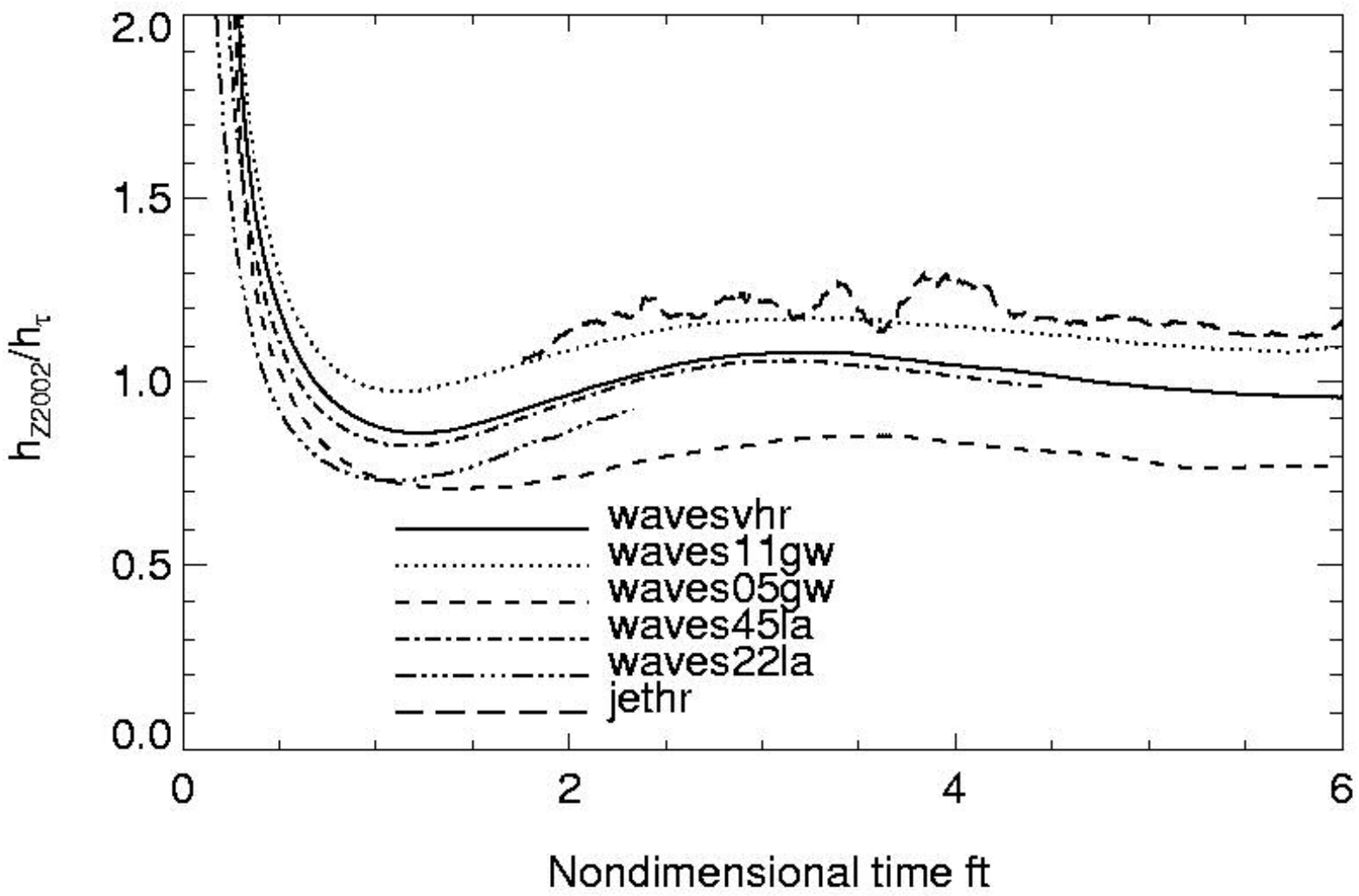
Normalized Boundary Layer Height small domain – grid size 6.25m



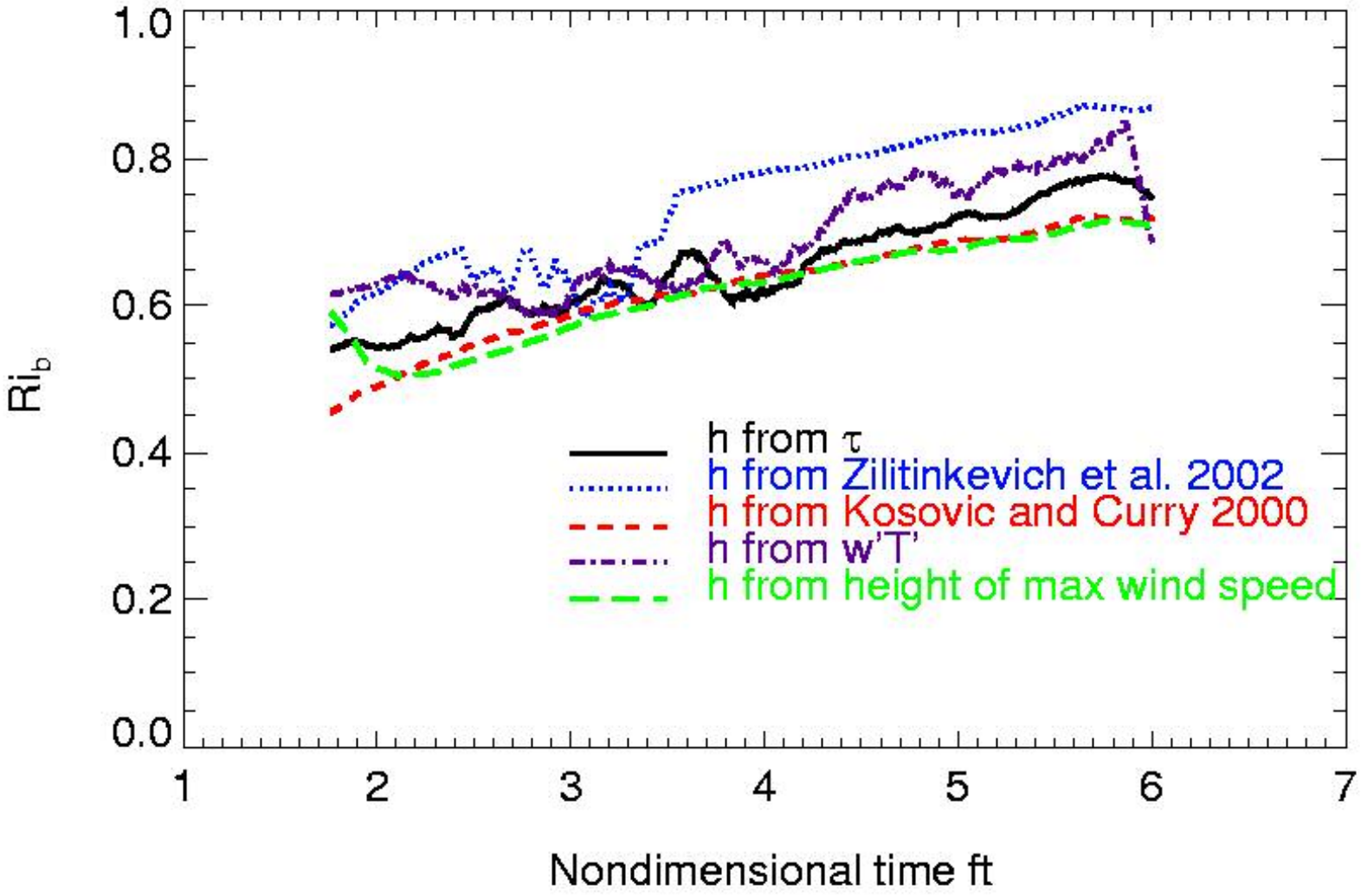
Normalized Boundary Layer Height
large domain – grid size 15m



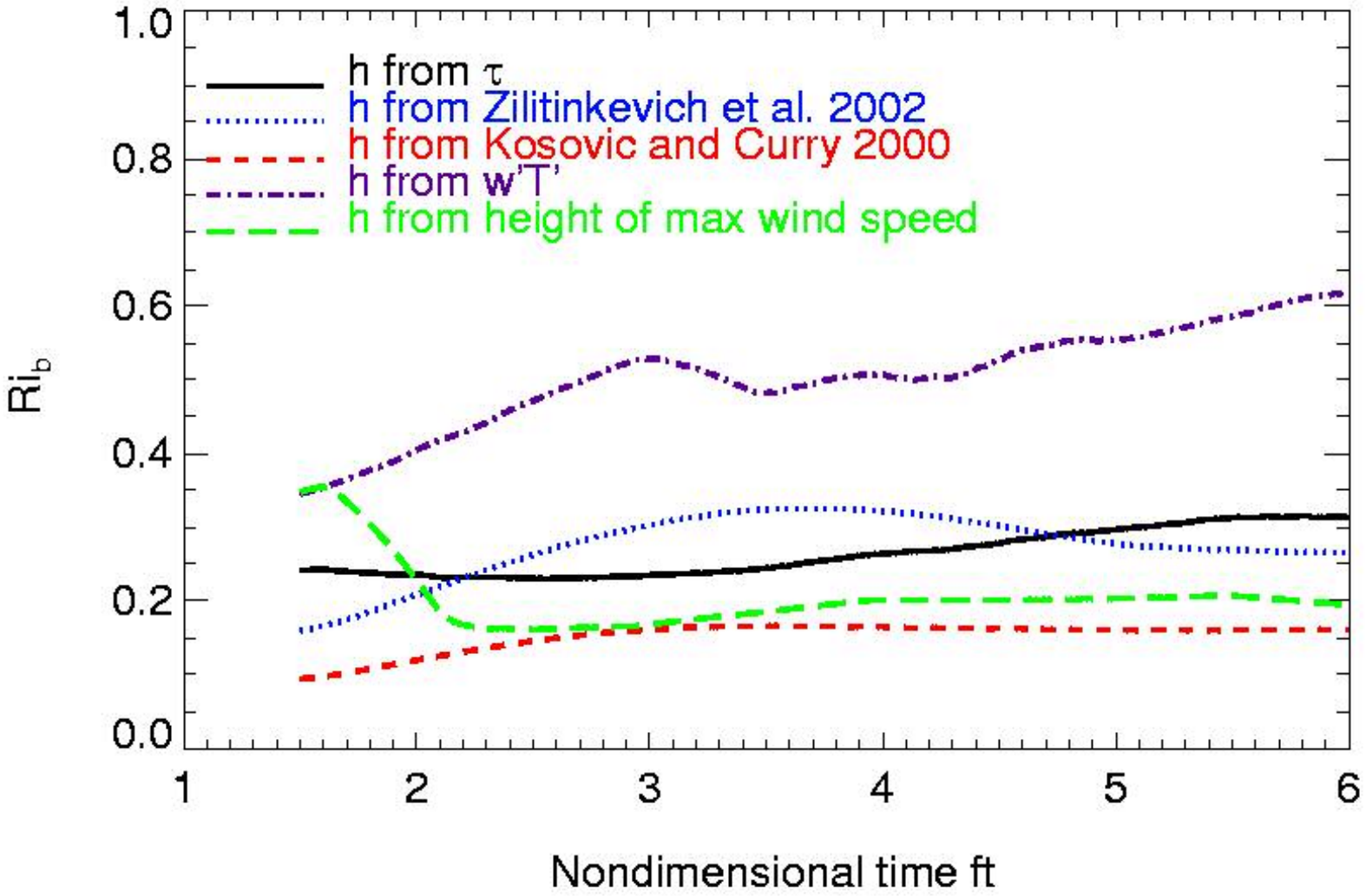
Boundary Layer Height (Zilitinkevich et al. 2002)



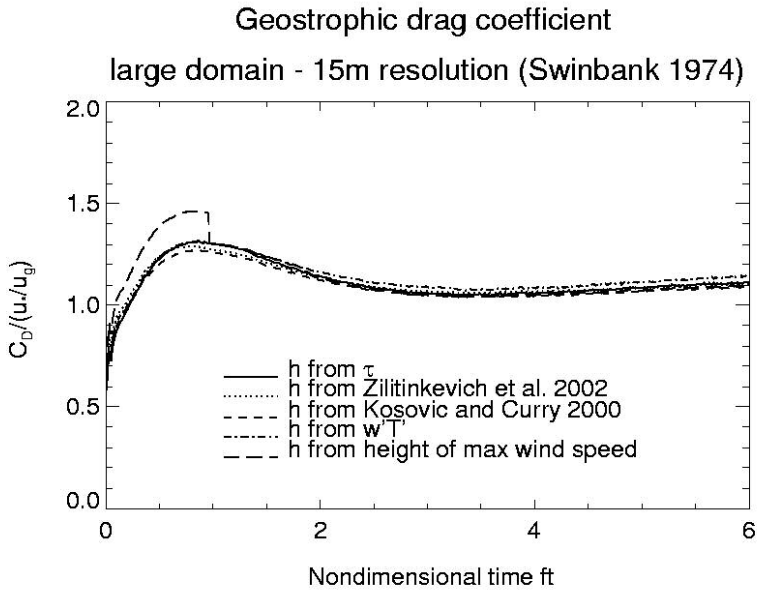
Bulk Richardson Number
small domain – grid size 6.26m

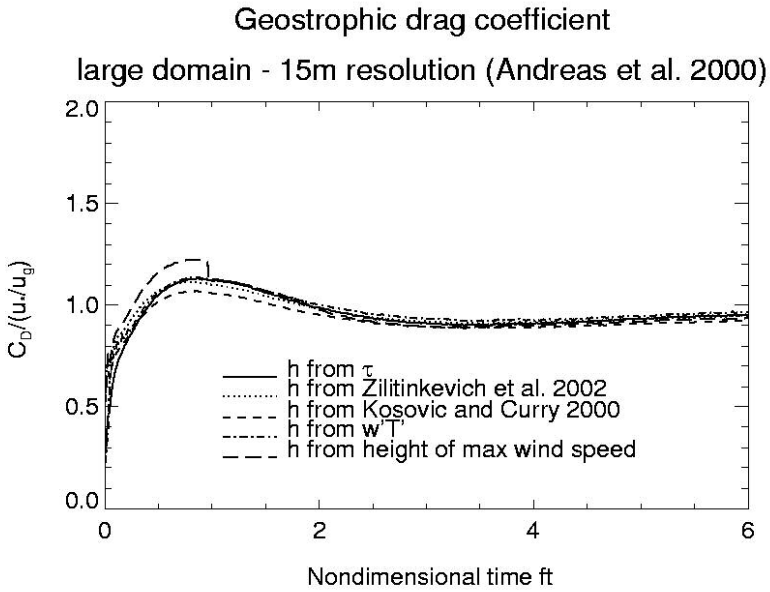


Bulk Richardson Number
large domain – grid size 15m



Geostrophic Drag Coefficient Computed from LES





Summary

- The height of the SBL (h) is typically used to model eddy viscosity and diffusivity; it is also important for accurate prediction of dispersion in stable boundary layers
- LES results indicate that the strength of the overlying inversion affects h via gravity wave – turbulence interaction
- The domain size for LES of SBLs must be large enough to resolve gravity waves aloft while the grid size must be sufficiently small to resolve SBL turbulence